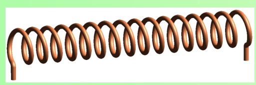
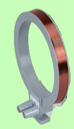
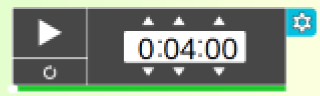
Magnetic fields	**Magnetic fields and magnetic flux density**

Learning objectives		
	MUST (C)	Draw magnetic field lines for different current-carrying wires
	SHOULD (B)	Recall and apply the equation for force on a current-carrying conductor in a magnetic field
	COULD (A/A*)	Describe a practical to determine the magnetic flux density of a current-carrying wire

STARTER: Think back to your GCSE studies. What were the rules for drawing magnetic field lines? Quickly sketch the magnetic field around a current-carrying a) straight wire, b) solenoid and c) flat coil.

EXTENSION: It used to be in Canada, now it's in the Arctic ocean and heading for Siberia at about 55 km per year. What is it, and what might happen now?

TECH & SCIENCE

EARTH'S MAGNETIC NORTH POLE IS HURTLING TOWARDS SIBERIA, AND ONE DAY THE WHOLE FIELD IS GOING TO FLIP

The first expedition to find the north magnetic pole, where the magnetic field points vertically downwards, was undertaken by James Clark Ross in 1831. Subsequent expeditions, and global observations from both Earth's surface and space, allow a reconstruction of the history of the north magnetic pole. Prior to 1990, the north magnetic pole moved at a sedate speed of approximately 0-15km/yr (0-9m/yr); but in the 1990s its speed dramatically increased to its present value of 50-60km/yr (31-37m/yr.)

The last global reversal, the Brunhes-Matuyama, occurred about 780,000 years ago, although a failed reversal, the Laschamp event, occurred around 41,000 years ago when the field temporarily reversed and rapidly switched back to its previous polarity.

Magnetic flips occur about three times per million years, which coupled with the current weakening trend of the global magnetic field by about 5 percent per century, has led to speculation that planet Earth may be headed for a reversal.

Magnetic fields	**Magnetic field and flux density**
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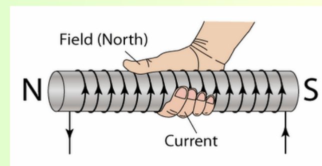
Magnetic fields

Magnetic fields can be produced either by permanent magnets, in which a magnetic field is produced by electrons around the nuclei, or by charged particles moving. A current-carrying wire produces a magnetic field, due to electrons moving within it.

Rules for drawing magnetic field lines



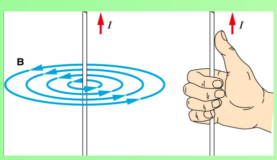
Magnetic field lines travel from north to south poles.

The direction of the field line at a point in a field is the direction of a force experienced by a 'free north'.

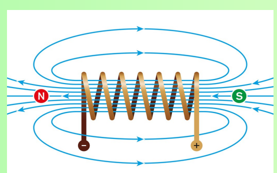
The field is strongest where field lines are closest together - equally spaced and parallel lines represent a uniform field.

For a wire, the right hand grip rule helps you to remember in which direction the field lines should be arrowed.

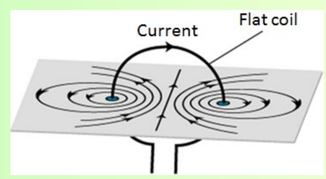
Wire



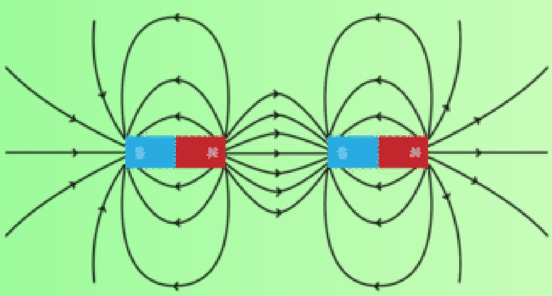
Solenoid



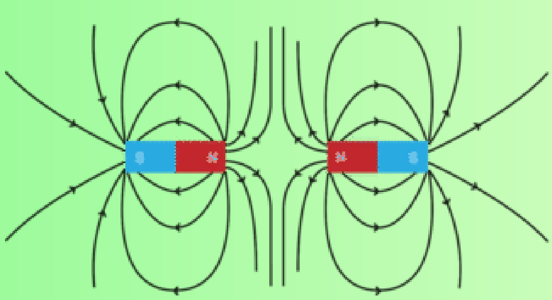
Flat coil



Remember convention for showing wire in/out plane of page: In ⊗ Out ⊙



Attraction



Repulsion

Magnetic fields	**Magnetic field and flux density**
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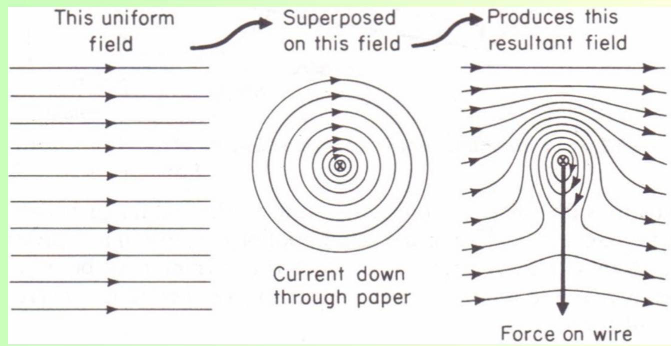
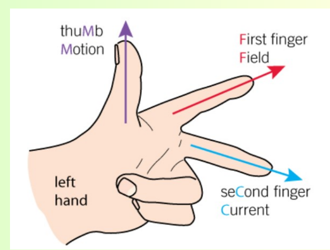
When a current-carrying wire is placed in a magnetic field, the two magnetic fields interact. The resultant field has areas of strong magnetic field, and areas of weaker magnetic field: the wire moves towards the weaker areas.



At GCSE, we learned that the direction can be predicted using Fleming's LH rule. We also learned that F = BIL where:



F = force (N)

B = magnetic flux density (T)

I = current

L = length of wire in field.

This assumes that the wire is at right angles to the field.

We can now extend this equation:

$F = BIL\sin\theta$, where θ is the angle between the magnetic field and the current direction.

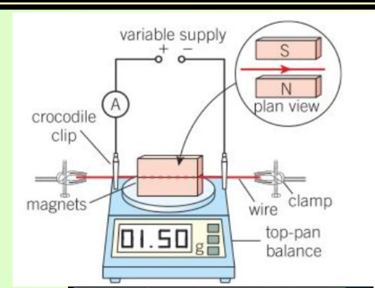
How can we use this to define the tesla?

1T is the magnetic flux density that will cause a wire carrying a current of 1A placed perpendicular to the magnetic field to experience a force of 1N per metre of its length.

Do you think that 1T is a large or small magnetic field?

Magnetic fields	**Magnetic fields and magnetic flux density**
COULD (A/A*)	Describe a practical to determine the magnetic flux density of a current-carrying wire

Task 1: The magnetic flux density around a current-carrying wire can be determined in the laboratory. Stick the diagram into your book and sequence the process, using the information in section 23.2 and making it clear which equations should be used.



Task 2: Answer the summary questions in section 23.2. If you feel confident with Fleming's LH rule, start with question 4.

4 a $F = BIL\sin\theta$, $F \propto I$ therefore the force is $5.0 \times 4 = 20\,\text{mN}$ [1]

b $F = BIL\sin\theta$, $F \propto B$ therefore the force is $5.0 \times 2 = 10\,\text{mN}$ [1]

c $F = BIL\sin\theta$, $F \propto L$ therefore the force is $0.30 \times 5.0 = 1.5\,\text{mN}$ [1]

5 $F = BIL\sin\theta$, $4.0 \times 10^{-3} = B \times 0.80 \times 0.028 \times \sin 38°$ [1]

$$B = \frac{4.0 \times 10^{-3}}{0.80 \times 0.028 \times \sin 38}$$ [1]

$B = 0.29\,\text{T}$ [1]

6 a The length of the loop on the left-hand side and perpendicular to the field experiences a force into the plane of the paper and the opposite side experiences a force out of the plane of the paper. [1]

Hence the loop will rotate clockwise if observed from the top. [1]

b torque $= Fd = (BIx) \times x$ [1]

torque $= (BI) \times x^2$ [1]

The product BI is constant; therefore torque $\propto$ cross-sectional area x^2. [1]

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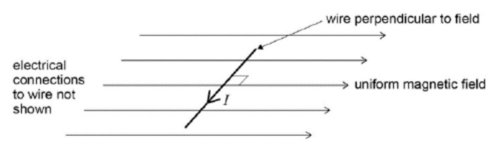
PLENARY: Calculate the mass of the wire.

Extension: The experimenter rotates the wire so that it is no longer perpendicular to the field. What will happen to the wire?

A horizontal straight wire of length 0.30 m carries a current of 2.0 A perpendicular to a horizontal uniform magnetic field of flux density 5.0×10^{-2} T. The wire 'floats' in equilibrium in the field.



What is the mass of the wire?

- **A** 8.0×10^{-4} kg
- **B** 3.1×10^{-3} kg
- **C** 3.0×10^{-2} kg
- **D** 8.2×10^{-1} kg